U.S. Department of the Interior
U.S. Geological Survey

Manganese Recycling in the United States in 1998

By Thomas S. Jones

U.S. GEOLOGICAL SURVEY CIRCULAR 1196–H

FLOW STUDIES FOR RECYCLING METAL COMMODITIES IN THE UNITED STATES

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

U.S. GEOLOGICAL SURVEY, RESTON, VIRGINIA : 2003
Version 1.0

Published online in the Eastern Region, Reston, Va., 2003.
Manuscript approved for publication February 6, 2003.

FOREWORD

As world population increases and the world economy expands, so does the demand for natural resources. An accurate assessment of the Nation's mineral resources must include not only the resources available in the ground but also those that become available through recycling. Supplying this information to decisionmakers is an essential part of the USGS commitment to providing the science that society needs to meet natural resource and environmental challenges.

The U.S. Geological Survey is authorized by Congress to collect, analyze, and disseminate data on the domestic and international supply of and demand for minerals essential to the U.S. economy and national security. This information on mineral occurrence, production, use, and recycling helps policymakers manage resources wisely.

USGS Circular 1196, "Flow Studies for Recycling Metal Commodities in the United States," presents the results of flow studies for recycling 26 metal commodities, from aluminum to zinc. These metals are a key component of the U.S. economy. Overall, recycling accounts for more than half of the U.S. metal supply by weight and roughly 40 percent by value.

Charles G. Groat
Director

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FIGURES

TABLE

CONVERSION FACTORS

Multiply	By	To obtain
	Length	
kilometer (km)	0.6214	mile
inch (in.)	25.4	millimeter
	Volume	
cubic foot (ft^3)	0.02832	cubic meter
	Mass	
gram (g)	0.03527	ounce avoirdupois
kilogram (kg)	2.205	pound avoirdupois
kilogram (kg)	32.1507	troy ounce
metric ton (t, 1,000 kg)	1.102	short ton (2,000 pounds)
troy ounce (troy oz)	31.10	gram

For temperature conversions from degrees Celsius (°C) to degrees Fahrenheit (°F), use the following:

$$°F = (1.8 \times °C) + 32$$

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ABSTRACT

This report describes the flow and processing of manganese within the U.S. economy in 1998 with emphasis on the extent to which manganese is recycled. Manganese was used mostly as an alloying agent in alloys in which it was a minor component. Manganese was recycled mostly within scrap of iron and steel. A small amount was recycled within used aluminum beverage cans. Very little manganese was recycled from materials being recovered specifically for their manganese content. For the United States in 1998, 218,000 metric tons of manganese was estimated to have been recycled from old scrap, of which 96 percent was from iron and steel scrap. Efficiency of recycling was estimated to be 53 percent, and the recycling rate, 37 percent. Metallurgical loss of manganese was estimated to be about 1.7 times that recycled. This loss was mostly into slags from iron and steel production from which recovery of manganese has yet to be shown economically feasible.

INTRODUCTION

The purpose of this study is to document the extent to which manganese is being recycled in the United States, to identify trends in domestic manganese recycling[1], and to determine the implications of these trends for sustainability of manganese use. The base year for the study is 1998.

Manganese (atomic number 25) is in Group 7 of the Periodic Table. In that table, its closest neighbors are, to the left, vanadium and chromium and, to the right, iron, cobalt, and nickel. Thus, it is not surprising that manganese should be considered a ferrous metal and that its major use is in iron-base alloys (steel and cast iron). Because manganese metal typically is brittle and unworkable, only a small amount can be used as an alloy in which manganese is the major component. Rather, manganese is used predominantly in alloys where it is a minor component, principally in steel and, to a lesser extent, aluminum. Manganese is essential to steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties.

In nonmetallurgical uses, the most common valences for manganese are two and four, and oxygen is the main element with which manganese is combined. Accordingly, the mineral and commodity chemistry of manganese centers on such compounds as manganous oxide (MnO), manganese dioxide (MnO_2), manganese carbonate ($MnCO_3$), and manganese sulfate ($MnSO_4$). Pyrolusite (a mineral form of manganese dioxide), braunite (an oxysilicate), and rhodochrosite (a manganese carbonate) are among the minerals more commonly found in manganese ores. In 1998, the leading producers of ore were Australia, Brazil, China, Gabon (the leading U.S. source), India, South Africa, and Ukraine.

When a reductant (carbon) is present in the charge to a process for making iron or steel, some manganese ore is used directly. Examples include addition to the charge to an iron blast furnace and direct smelting of ore during steelmaking (Japan). For the most part, however, ore is smelted and reduced to its metallic content by carbon predominantly in submerged-arc electric furnaces but also in blast furnaces. Because manganese ores typically contain iron as well, the result of smelting is an iron-bearing ferroalloy, which is used subsequently to add manganese to liquid metal during steelmaking. The principal manganese ferroalloys and their typical components are high-carbon ferromanganese (78 percent manganese, 7 percent carbon, balance mostly iron) and silicomanganese (66 percent manganese, 17 percent silicon, 2 percent carbon). An electrolytic process is used to obtain electrolytic manganese dioxide (EMD) and most manganese metal, the two other forms in which manganese is commercially most used. The sequence of steps usually used in producing these two materials is similar—leaching manganese feed with sulfuric acid and electrodepositing EMD or metal from the leach liquor after it has been purified.

Metallurgical applications account for most domestic manganese consumption, of which 85 to 90 percent has been going to steelmaking and about 8 percent, to the manufacture of dry cell batteries. The preponderance of the manganese used domestically for making batteries is now EMD because usage of natural battery ore has declined greatly. The manufacture of manganese chemicals, such as potassium permanganate, and agricultural use of manganese in animal feed and plant fertilizer as oxide, sulfate, and oxysulfate together account for another 5 percent of use. These patterns of domestic use are typical for other industrialized countries having well-developed steel industries.

[1]Definitions for select words are found in the Appendix.

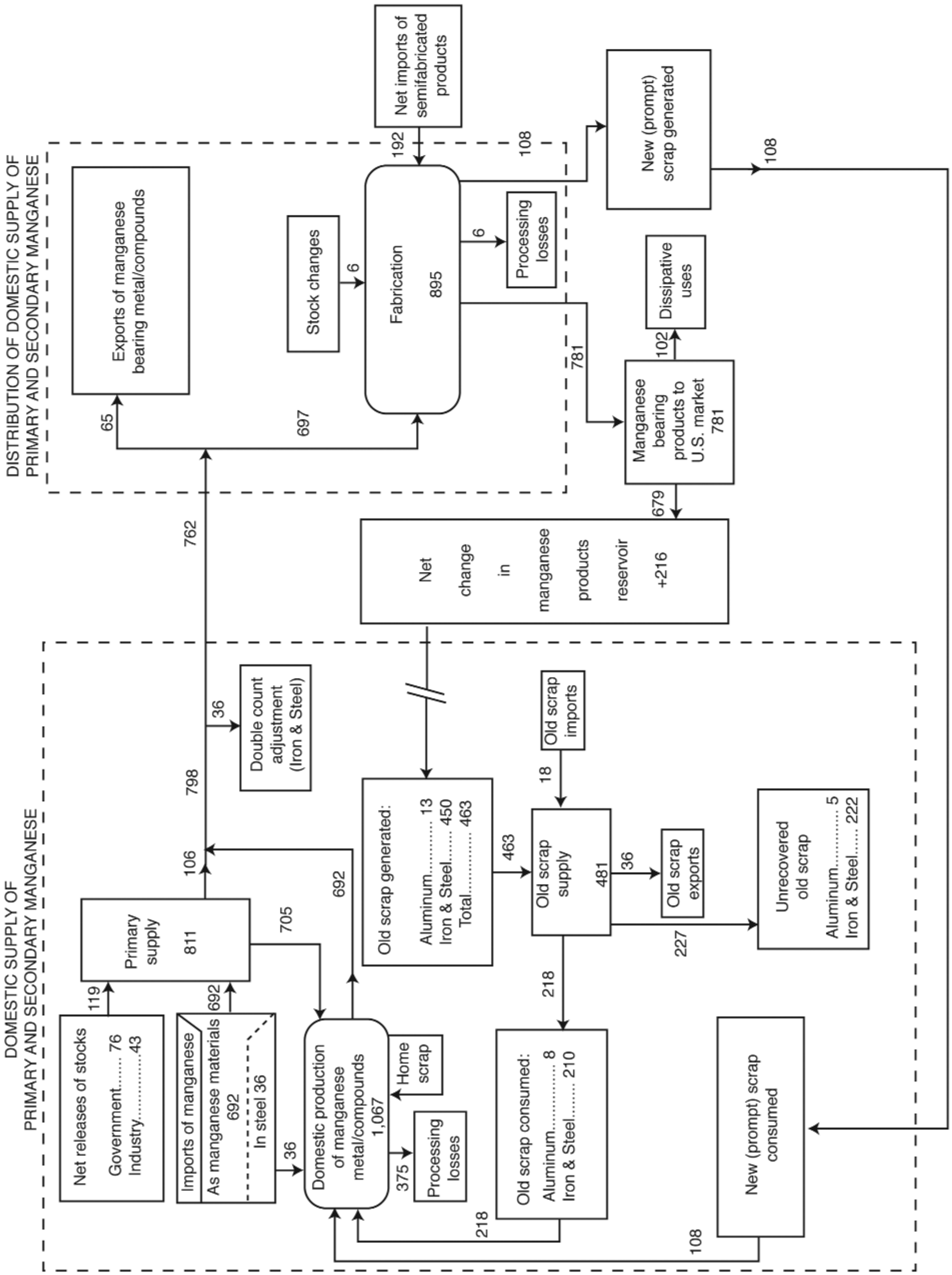

Figure 1. U.S. manganese materials flow in 1998. Values are in thousand metric tons of manganese content.

Table 1. Salient statistics for U.S. manganese-bearing in 1998.
[Values in thousand metric tons of contained manganese, unless otherwise specified]

Old scrap:	
Generated[1]	463
Consumed[2]	218
Consumption value	$120 million
Recycling efficiency[3]	53 percent
Supply[4]	481
Unrecovered[5]	227
New scrap consumed[6]	108
New-to-old-scrap ratio[7]	33:67
Recycling rate[8]	37 percent
U.S. net exports of scrap[9]	18
Value of U.S. net exports of scrap	$10 million

[1]Old scrap that will theoretically become obsolete in the United States in 1998. Dissipative uses are excluded.

[2]Old scrap recycled in 1998.

[3](Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imported).

[4]Old scrap generated plus old scrap imported.

[5]Old scrap supply minus old scrap consumed minus old scrap exported.

[6]Includes prompt industrial scrap but excludes home scrap.

[7]Ratio of quantities consumed, in percent.

[8]Fraction of supply that is scrap on an annual basis. It is defined as (consumption of old scrap plus consumption of new scrap) divided by apparent supply (see appendix), measured in weight and expressed as a percentage.

[9]Trade in scrap is assumed to be principally in old scrap.

For 1998, the average price for U.S. delivery of metallurgical-grade ore was assessed at $2.40 per metric ton unit, on the basis of cost, insurance, and freight; and the year-average free-on-board price for imported high-carbon ferromanganese was $502 per long ton of alloy (Jones, 2000, p. 49.2-49.3). At per kilogram of contained manganese, these prices equate to 24 cents for ore and 63 cents for high-carbon ferromanganese. For 1993 through 1998, the ore prices were reasonably steady following a decline from a peak of $3.78 per metric ton unit in 1990 (Jones, 1999). In the 1990s through 1998, the price trend for high-carbon ferromanganese had been gradually declining from a maximum of about $650 per long ton of alloy in 1990.

The salient statistics for manganese-bearing scrap given in table 1 are based mainly on and determined by the status of recycling for iron and steel. The recycling of iron and steel scrap is the subject of another report by the U.S. Geological Survey (USGS) to which the reader is referred for details (Fenton, in press). Those aspects that deal with iron and steel scrap are given only in summary form in this report. Two of the three ratios given in table 1 are nearly the same as the ratio for manganese and iron and steel scrap—old scrap recycling efficiencies of 53 percent for manganese and 52 percent for iron and steel scrap and new-to-old-scrap ratios of 33 to 67 for manganese and 34 to 66 for iron and steel scrap. The lower recycling rate for manganese (37 percent) than that for iron and steel scrap (41 percent) reflects the relatively large loss of manganese during metallurgical processing. Figures given in table 1 for the value of the manganese units in scrap are based on a unit value of $560 per metric ton of manganese as estimated from foreign trade data for 1998.

The only significant metal form recovered specifically because of its manganese content was wear-resistant steel in which the manganese content typically is about 12 percent (so-called Hadfield steel). Otherwise, recovery of manganese in metal was incidental to the recycling of another metal—iron in the case of steel scrap and iron castings and aluminum in the case of used beverage cans (UBCs).

A small amount of manganese was recovered through recycling of dry cell batteries or manganese-bearing wastes generated in battery manufacture. One battery company formed a partnership with a steel company whereby more than 1,000 metric tons per year of scrap from the battery company was to be consumed in steel production (Watson, Andersen, and Holt, 1998). With a manganese content of 20 percent, this volume might be expected to contain about 200 metric tons (t) of manganese (Ferlay and Weill, 2000). Battery recycling is not considered further in this report because the quantity of manganese being recycled from batteries was relatively small and not precisely known.

SOURCES

Figure 1 is a composite derived from knowledge of the flows of manganese and manganese-bearing materials, such as iron and steel scrap and aluminum UBCs. The data for the majority of the diagram are based on the material flow relations for iron and steel scrap, in which the manganese content is taken to be 0.6 percent throughout, as suggested by Jones (1994, p. 42), for average manganese content of steel. Scrap of high-manganese Hadfield steel is not treated as a separate item. Its annual domestic production was not known but is estimated to be about 50,000 t as inferred from shipments (Kirgin, 2000). Even if it were recycled at a 75-percent rate, the manganese content of manganese steel scrap would only be about 2 percent of the estimated manganese content of the 35 million metric tons (Mt) of iron and steel scrap consumed/recycled in 1998.

The inputs to the primary supply of manganese as diagrammed in the upper left of figure 1 consist of drawdowns of industry and Government stocks of manganese materials, imports of manganese materials (dioxide, ferroalloys, metal, ores), and imports of raw steel. Of this, 4 units (4,000 t) of manganese exported as ore and 102 units of manganese destined for battery and chemical uses bypass metallurgical processing and flow directly to the output (right) side of the diagram. The balance of the primary supply goes mainly into the manufacture of ferroalloys and steel. Most of the ferroalloys and metal were used in steelmaking, but 31 units were exported and are included within the 65 units of exports.

The principal data sources for this report are Fenton (2000b, c), Jones (2000), and the sources upon which the data in those chapters were based. Quantities for manganese end uses are obtained from data collected by means of the Manganese Ore and Products Survey of the USGS.

The types of manganese-bearing products ultimately becoming scrap and the industries in which they were used can be inferred by considering the pattern of manganese consumption. This is shown for 1979 through 1998 in figure 2, in which an estimated total of 730,000 t of manganese was used for 1997; this replaced the anomalously low total of 643,000 t published in the 1999-2001 USGS Minerals Yearbooks. Construction, machinery, and transportation have been the larger of the consuming sectors. The “All Other” category includes steel for nonspecified uses as well as a number of other minor steel categories (appliances and equipment, cans and containers, and oil and gas industries).

OLD SCRAP GENERATED

Old scrap generated was mostly iron and steel scrap. The first step in estimating this component was to assign lifetimes to various steel products as categorized in the steel shipments data published in the Annual Statistical Reports of the American Iron and Steel Institute. For iron and steel scrap, the weighted average product life was 19 years. For each product, the quantity of steel becoming obsolete in 1998 was taken to be that shipped at the beginning of its life. For example, the quantity for a product with a lifetime of 20 years was the quantity of that product shipped in 1978.

Scrap from aluminum UBCs made only a small contribution to old scrap generated. Estimation of the addition to manganese recycling from UBCs is discussed in detail in the “Processing of Manganese-Bearing Scrap” section of this report.

NEW SCRAP

New scrap consists entirely of iron and steel scrap that results from fabricating operations and is often returned directly from the fabricator to the originating steel plant. The quantity of new scrap generated is taken as being equal to 15 percent of apparent consumption of steel (Fenton, in press). Apparent consumption of steel in 1998 was 118 Mt (Fenton, 2000a). The quantity of new scrap consumed is assumed to be equal to that generated without losses or additions. As indicated in figure 1, the quantity of new scrap generated was about one-fourth of the quantity of old scrap generated.

DISPOSITION

The supply of old scrap consists of old scrap from iron and steel scrap plus a small amount of old scrap from UBCs (discussed in the section “Used Aluminum Beverage Cans”). Output from old scrap supply includes exports and unrecovered scrap with the balance going into current consumption (recycled). Import and export quantities are obtained from the trade statistics for iron and steel scrap. The quantity consumed is obtained from iron and steel scrap consumption data as provided by a USGS survey from which are deducted the amounts of consumption of home and prompt scrap. The number of manganese units in the quantity consumed was 210,000 t. The amount of unrecovered scrap is estimated to be the difference needed to obtain a balance for supply of old scrap.

Included in the right-hand part of figure 1 is the dissipative loss of 102,000 t of manganese from the manufacture and use of manganese-containing batteries and chemicals. This was the quantity obtained for 1998 from the USGS Manganese Ore and Products Survey of plants where batteries, EMD, or such manganese chemicals as manganese sulfate and potassium permanganate are made or that supplied manganese raw material that ultimately went into such items as animal feed and plant micronutrients. The battery total includes imports of manganese dioxide. The average lifetime of batteries and chemicals was assumed to be less than 1 year.

RECYCLING EFFICIENCY FOR OLD SCRAP

Recycling efficiency is the amount of scrap recovered and reused relative to the amount theoretically available to be recovered and reused. The recycling efficiency for manganese-bearing scrap is calculated to be 53 percent on the basis of the recycling of old iron and steel scrap plus a small amount of old UBC scrap.

By using a different manganese material flow model, Gabler (1995, p. 19) estimated the amount of manganese contained in old scrap that was recycled to correspond to 12 percent of the apparent consumption in 1990. The equivalent percentage is 28 percent for the flow model for 1998 shown in figure 1.

Recycling of iron and steel scrap has been going on for more than 200 years, and that of UBCs, for about 30 years. Nearly one-half of domestic steel production in 1998 was from plants based solely on the use of scrap. Recycling efficiency is expected to remain about the same for iron and steel scrap because of competition from alternative sources of iron units. The aluminum industry expects that the trend in recycling rate for UBCs will be a slow but gradual increase. For information on the recycling of iron and steel, see Fenton (in press).

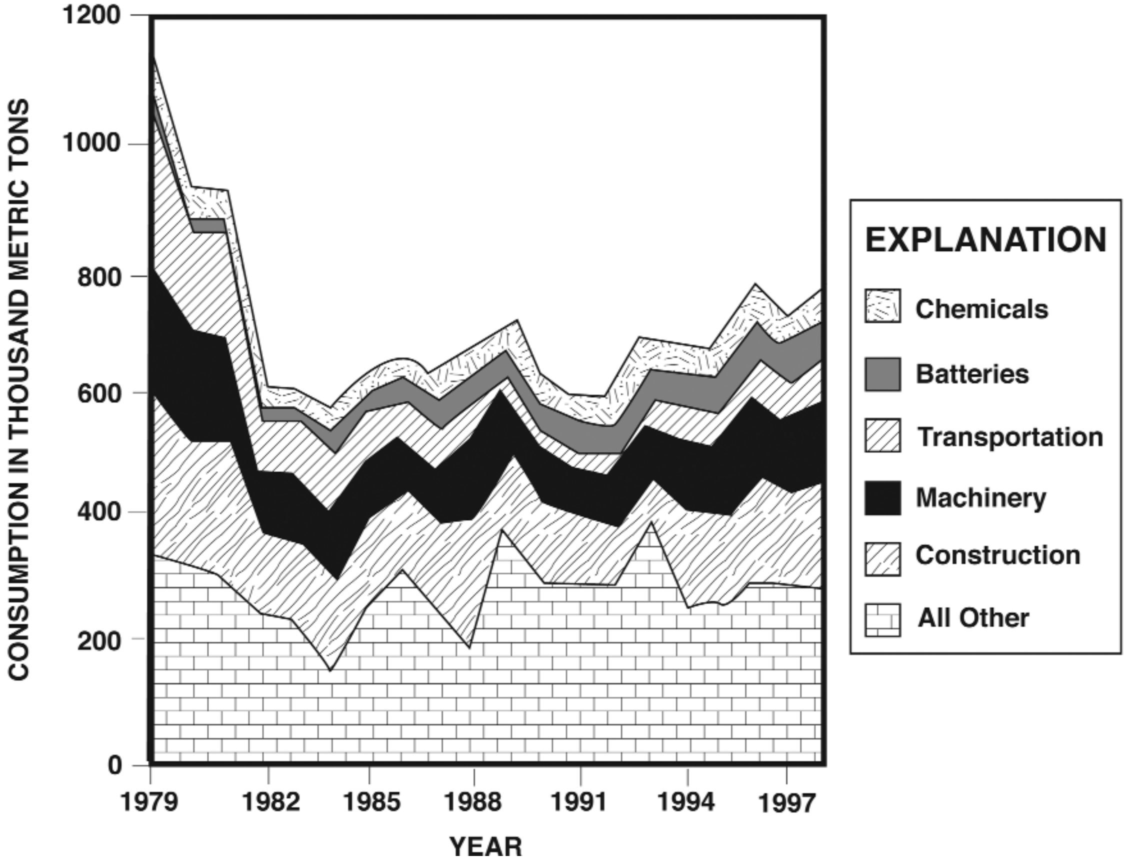

Figure 2. U.S. manganese consumption, by end-use pattern, from 1979 through 1998.

INFRASTRUCTURE

No ore with a manganese content of more than 35 percent was mined domestically in 1998. Consequently, all primary units of manganese were obtained from either imported ore or ore released from Government stockpiles.

The chief facility where manganese was smelted and/or extracted was near Marietta, Ohio, and was the only site where manganese ferroalloys were produced domestically. In 1998, this facility, which was operated by Elkem Metals Co., accounted for more than 50 percent of total U.S. consumption of manganese ore. Ownership of this facility changed in 1999 to France's Eramet; it was renamed Eramet Marietta Inc. In 2000, annual production of manganese ferroalloys there was reported to be 65,000 t of silicomanganese and 104,000 t of various grades of ferromanganese (Platt's Metals Week, 2000); manganese metal and EMD also were produced electrolytically at this site. Several other companies produced EMD—Eveready Battery Co. in Ohio, Kerr-McGee Chemical LLC in Mississippi, and Erachem Comilog, Inc. (formerly Chemetals Inc.), in Tennessee. Electrolytic metal was produced domestically at another site in Nevada (also Kerr-McGee). Subsequently, domestic production of manganese metal ended, first at Eramet Marietta in 2000 and then at Kerr-McGee in 2001.

With regard to the infrastructure of iron and steel scrap recycling [discussed by Fenton (in press) in more detail], a large amount of scrap is generated by a multitude of firms and facilities located in the northern and eastern parts of the country.

Monthly and annual reports of the USGS for Iron and Steel Scrap and for Aluminum provide details of foreign trade in scrap of these materials, especially trade of the United States. The United States historically has been a net exporter of iron and steel scrap.

In chapter 81 of the Harmonized Tariff Schedule for U.S. imports, the part that pertains to "Other base metals" contains a "Waste and scrap" subcategory (8111.00.3000) for manganese. The quantity of imports reported in this subcategory typically is about 200 t or less, most of which is from Canada. The nature of the material being reported under this subcategory is not well known and probably consists of various manganese-bearing drosses, residues, and steel and/or iron items or perhaps none of these. This material is not included within the manganese materials flow discussed in this report except that the 215 t of so-called manganese waste and scrap reported as having been imported is assigned an average manganese content of 50 percent and, on that basis, is included within total manganese imports.

PROCESSING OF MANGANESE-BEARING SCRAP

IRON AND STEEL SCRAP

Of the 811,000 t of manganese units from stocks and imports that compose primary supply, 705,000 t goes into domestic production (figure 1). Domestic production includes the sequence of manufacturing steps that produce manganese ferroalloys and/or metal, raw steel in whose manufacture domestic plus imported ferroalloys and metal are consumed, and finally steel mill shapes that are shipped to fabricators or end users. By means of a balance between the total inputs and outputs for production that relate to iron and steel, the metallurgical loss or nonutilization of manganese was calculated to be 368,000 t. This signifies a loss rate of 52 percent, which is somewhat greater than the range of 40 to 50 percent that is presumed to apply for manganese loss in steelmaking in the 1990s (Jones, 1994, p. 15). The 52-percent figure does not seem unreasonable, however, when one considers that it includes not only losses in steelmaking, but also those in the manufacture of ferroalloys and metal. Presumably, most of the manganese not ending up in product becomes a constituent of slag, at least some of which is usable.

Most of the processing of iron and steel scrap takes place prior to its arrival at the steel plant. Operations at the steel plant consist of keeping scrap segregated according to its chemical and physical characteristics and cutting up bulky home scrap into more manageable pieces. Because of the high temperatures involved, iron and steel scrap is completely melted in the steelmaking operation. Refining typically includes an oxidation step; for example, by injection of gaseous oxygen. This causes the losses of carbon to gas and of some iron, manganese, and silicon to slag. The recycling model for iron and steel shows a processing loss for iron of 1 Mt, which is presumed to carry with it a manganese loss of 6,000 t, thus raising processing losses calculated so far to 374,000 t (Fenton, in press).

Small amounts of iron and steel are unrecoverably lost through such dissipative causes as corrosion. Some old scrap can be regarded as temporarily unrecovered through its disposal in landfills or abandonment in place. The manganese units in unrecovered iron and steel scrap were estimated on the basis of the iron and steel model to be 222,000 t.

Following this model, the amount of old scrap generated (that is, the manganese content of the 75 Mt of iron and steel that became obsolete in 1998) was 450,000 t. As stated earlier in the section “Old Scrap Generated,” the weighted average recycling time was 19 years. The material savings from recycling of iron and steel scrap is estimated to be 1 t of iron ore and 0.6 t of coal per metric ton of scrap recycled. The energy saved from recycling of iron and steel scrap was equivalent to that required to supply electricity to about one-fifth of domestic households (Fenton, in press).

In view of its quality and known composition, home scrap within the steel plant is assumed to be recycled within 1 year of its generation. Similarly, new scrap generated during fabricating operations is relatively clean and of known composition and requires little preparation. Consequently, prompt scrap rapidly finds its way back to steel plants. This type of scrap is usually recycled directly; for example, from an automobile plant back to the steel plant from which the steel originally came.

USED ALUMINUM BEVERAGE CANS

Some of the quantities shown in figure 1 reflect the relatively small amounts of manganese recovered by recycling of UBCs. On a weight basis, 75 percent of aluminum beverage can (ABC) bodies are made from alloy 3004, and 22 percent of lids, from alloy 5182. The nominal manganese content of alloy 3004 is 1.1 percent, and that of alloy 5182 is 0.35 percent. The conditions for UBC recycling in 1998 were taken to be the same as those that had been projected for 1997—average UBC manganese content of 0.92 percent and melt loss of 9.3 percent (Sanders and Trageser, 1990, p. 197). Melt loss is the only source of manganese loss in UBC recycling; loss of manganese is not due to burn-off or vaporization (R.E. Sanders, Jr., Technical Consultant, Aluminum Company of America, oral commun., December 4, 2000). UBCs were processed in facilities dedicated to their recycling.

The Aluminum Association estimated the net weight of new ABCs shipped in 1998 to be 3.09 billion pounds (1.4 Mt) and the rate of their recycling to be 62.8 percent (Aluminum Association, Inc., 1999). At 0.92 percent, the manganese content of the quantity shipped is approximately 12,900 t, which is assumed to be the quantity of old scrap eventually generated from this source. UBC recycling—from can shipment to use to disposal and recovery—takes place rather rapidly so that recovery is assumed to take place within the year of generation. At a recycling rate of 62.8 percent, the manganese content of the old scrap recovered (consumed) is 8,100 t. The unrecovered quantity of manganese is 4,800 (12,900 minus 8,100) t, or a rounded 5,000 t, which is only about 2 percent of total unrecovered old scrap. At a 9.3-percent melt loss rate, the loss in processing the 8,100 t of manganese recovered from UBCs in old scrap is about 750 t, or a rounded 1,000 t. Incorporation of this with the process losses mentioned in the “Iron and Steel Scrap” section increases the total processing loss of manganese to 375,000 t.

SUMMARY AND OUTLOOK

Trends in the recycling of manganese are largely determined by trends in the recycling of iron and steel, which has accounted for 85 to 90 percent of manganese consumption. Steel is the more-important industry with a production of about 10 times that for cast iron. Consequently, the majority of manganese consumption is accounted for by production of raw steel (primary shapes).

The precipitous drop in manganese consumption between 1979 and 1982, which is shown in figure 2, is attributed mainly to a large decrease in raw steel production owing to adverse economic conditions and a significant decrease in the amount of manganese used per metric ton of steel produced. This decline in unit consumption was a gain from the adoption of new steelmaking technologies in the early 1980s, such as the use of combined blowing (Jones, 1994, p. 36). After 1983, the trend in total manganese consumption has been similar to that for raw steel production (about 1.8-percent-per-year growth). Assuming no significant change in manganese unit consumption, forecasts of the International Iron and Steel Institute suggest that the annual growth rate for total manganese consumption during the coming decade will be no greater than that of the past one (Iron & Steelmaker, 1999).

Figure 2 also shows that the distribution of manganese consumption among end uses has changed little with time. For the reasonably foreseeable future, this distribution pattern will remain about the same. Manganese consumption in batteries has been growing at a faster rate (about 6 percent per year) than steel-related uses but still accounts for less than 10 percent of total demand.

Recycling of iron and steel scrap is a well-established component of domestic steel production. Supply of iron units for steel production now is about evenly divided between iron ore plus some scrap (integrated steelmaking) and all scrap except for a small proportion of direct-reduced iron [electric arc furnace (EAF) mills]. By 2000, the EAF process could be used in 47 percent of domestic steel production. Because the share of domestic steel production taken by EAF mills has been growing steadily, these mills could be the dominant process by 2010 (Stubbles, 2000). This will provide the motivation for maintaining domestic recycling of manganese-bearing iron and steel scrap.

On a much smaller scale, recycling of UBCs has reduced the primary manganese requirement for aluminum beverage cans. Recycling of household batteries, which is an activity that is in its infancy, has the potential to make a small contribution to manganese recycling. One of the original motivations for battery recycling—preventing mercury loss to the environment—has been greatly diminished because deliberate additions of mercury to the battery mix are no longer made.

From the standpoint of sustainable use of manganese, reducing manganese loss in metallurgical processing would appear to be a major subject for investigation and is always of interest as a way of cutting costs. The relations given in figure 1 indicate that almost one-half as much manganese is lost in metallurgical operations as is contained in products going into use. These relations also indicate that nearly 90 percent of metallurgical losses were compensated for by the level of scrap recycling. Efforts to recover manganese from steelmaking slags date back to at least World War II, but development of a commercially feasible method has not been achieved nor seems likely to be for the foreseeable future (Jones, 1994, p. 29). A major difficulty is that the manganese content of steelmaking slags is relatively low (typically 7 percent or less). Significant quantities of iron and steel slags are used in construction and road building and for other purposes. These usages do not constitute a use of their manganese values per se.

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APPENDIX—DEFINITIONS

apparent consumption. Primary plus secondary production (old scrap) plus imports minus exports plus adjustments for Government and industry stock changes.

apparent supply. Apparent consumption plus consumption of new scrap.

dissipative use. A use in which the metal is dispersed or scattered, such as paints or fertilizers, making it exceptionally difficult and costly to recycle.

downgraded scrap. Scrap intended for use in making a metal product of lower value than the metal product from which the scrap was derived.

home scrap. Scrap generated as process scrap and consumed in the same plant where generated.

new scrap. Scrap produced during the manufacture of metals and articles for both intermediate and ultimate consumption, including all defective finished or semifinished articles that must be reworked. Examples of new scrap are borings, castings, clippings, drosses, skims, and turnings. New scrap includes scrap generated at facilities that consume old scrap. Included as new scrap is prompt industrial scrap—scrap obtained from a facility separate from the recycling refiner, smelter, or processor. Excluded from new scrap is home scrap that is generated as process scrap and used in the same plant.

new-to-old-scrap ratio. New scrap consumption compared with old scrap consumption, measured in weight and expressed in percent of new plus old scrap consumed (for example, 40:60).

old scrap. Scrap including (but not limited to) metal articles that have been discarded after serving a useful purpose. Typical examples of old scrap are electrical wiring, lead-acid batteries, silver from photographic materials, metals from shredded cars and appliances, used aluminum beverage cans, spent catalysts, and tool bits. This is also referred to as postconsumer scrap and may originate from industry or the general public. Expended or obsolete materials used dissipatively, such as paints and fertilizers, are not included.

old scrap generated. Metal content of products theoretically becoming obsolete in the United States in the year of consideration, excluding dissipative uses.

old scrap recycling efficiency. Amount of old scrap recovered and reused relative to the amount available to be recovered and reused. Defined as (consumption of old scrap (COS) plus exports of old scrap (OSE)) divided by (old scrap generated (OSG) plus imports of old scrap (OSI) plus a decrease in old scrap stocks (OSS) or minus an increase in old scrap stocks), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{OSE}}{\text{OSG} + \text{OSI} + \text{decrease in OSS or} - \text{increase in OSS}} \times 100$$

old scrap supply. Old scrap generated plus old scrap imported plus old scrap stock decrease.

old scrap unrecovered. Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

primary metal commodity. Metal commodity produced or coproduced from metallic ore.

recycling. Reclamation of a metal in usable form from scrap or waste. This includes recovery as the refined metal or as alloys, mixtures, or compounds that are useful. Examples of reclamation are recovery of alloying metals (or other base metals) in steel, recovery of antimony in battery lead, recovery of copper in copper sulfate, and even the recovery of a metal where it is not desired but can be tolerated—such as tin from tinplate scrap that is incorporated in small quantities (and accepted) in some steels, only because the cost of removing it from tinplate scrap is too high and (or) tin stripping plants are too few. In all cases, what is consumed is the recoverable metal content of scrap.

recycling rate. Fraction of the apparent metal supply that is scrap on an annual basis. It is defined as (consumption of old scrap (COS) plus consumption of new scrap (CNS)) divided by apparent supply (AS), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{CNS}}{\text{AS}} \times 100$$

scrap consumption. Scrap added to the production flow of a metal or metal product.

secondary metal commodity. Metal commodity derived from or contained in scrap.